



# SYSTEMS ENGINEERING AND INTEGRATION



## Systems Engineering Processes Applied To Ground Vehicle Integration at US Army Tank Automotive Research, Development, and Engineering Center (TARDEC)

**Dr. Bruce Brendle and Andrew Yee**

Report Documentation Page			Form Approved OMB No. 0704-0188		
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1. REPORT DATE <b>19 AUG 2010</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Systems Engineering Processes Applied To Ground Vehicle Integration at US Army Tank Automotive Research, Development, and Engineering Center (TARDEC)</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) <b>Dr. Bruce Brendle Andrew Yee</b>				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA</b>				8. PERFORMING ORGANIZATION REPORT NUMBER <b>21065</b>	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S) <b>TACOM/TARDEC</b>	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) <b>21065</b>	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES <b>Presented at NDIAs Ground Vehicle Systems Engineering and Technology Symposium (GVSETS), 17 22 August 2009, Troy, Michigan, USA, The original document contains color images.</b>					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>SAR</b>	18. NUMBER OF PAGES <b>20</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

## Mission:

CGVDI provides the Department of Defense a single project management office that coordinates activities across RDECOM and DoD to conduct the complete spectrum of activities required for design, development, fabrication, integration and testing of ground systems (manned or unmanned) from engineering changes to full system prototypes in order to meet the needs of the warfighter.

## Description

- Leverages RDECOM and DoD capabilities in a repeatable process to apply rigorous systems engineering to ground systems integration
- Provides customer partners a single entry point for cost, schedule, performance and risk management of system integration projects

## Notable Recent Accomplishments

- MRAP Capability Insertion for Caiman, MaxxPro, RG-31 and RG-33 Systems
- Command and Control on the Move (Stryker and MRAP Integrations)
- Robotic Deployment System

*Employs TARDEC organic Concepts, Analysis, System Simulation and Integration (CASSI), System Engineering (SE), and significant contributions from other RDECs and Organizations*

### CGVDI Projects (active):

- MRAP Capability Insertion
- C2OTM\* – MRAP
- C2OTM\* – Stryker
- LAV-R Upgrade
- RS-JPO
- PM-AMS

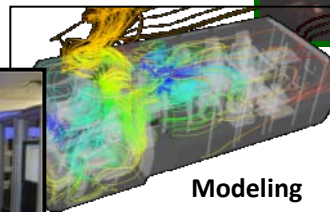
\*Command & Control On The Move



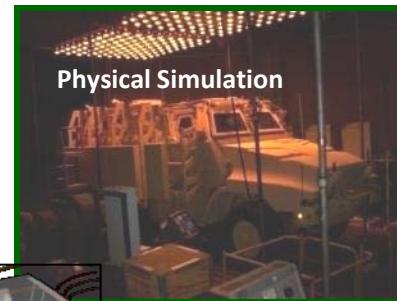
User Jury



C4 Integration Bench

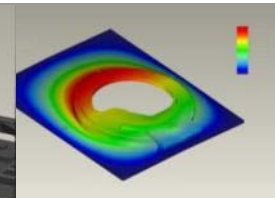


Modeling

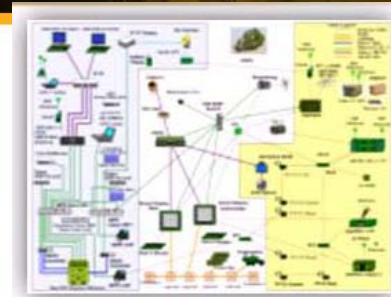


Physical Simulation

RWS System Integration

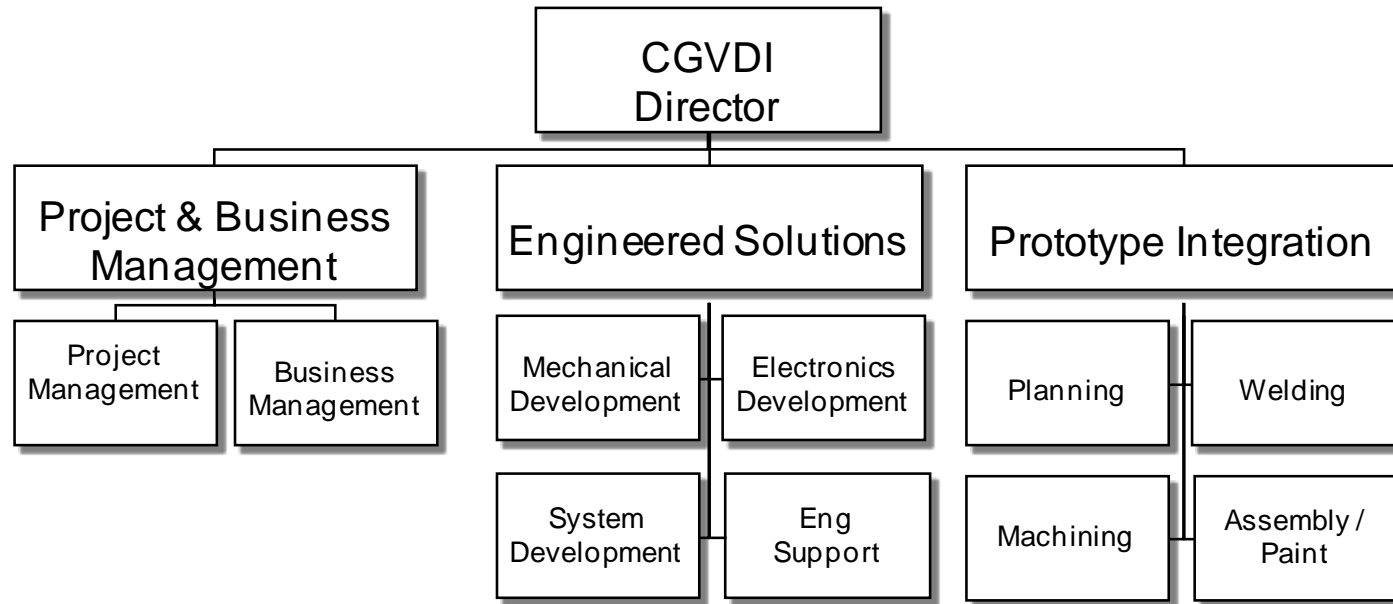


System Architecture



### MRAP Capability Insertion

- Vanguard
  - CROWS II Remote Weapon Station
  - Boomerang
  - Double Shot
- LRAS3
- Check 6 Camera
- OGPK Overhead Protection
- Overhead Wire Mitigation
- IBIS TEK Lights
- RPG Protection
- Power Upgrade (derived requirement)
- C4I Architecture (derived requirement)
- Thrown Object Protection System



CGVDI combines TARDEC's Ground Vehicle Integration Center and Prototype Integration Facility to create an improved, integrated capability.



# CGVDI Projects

## SYSTEMS ENGINEERING AND INTEGRATION

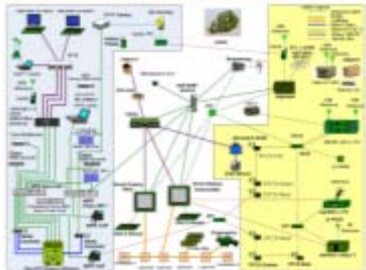


- Initial MRAP CI Scope: Capability Insertion System Integration for Caiman, MaxxPro, RG-31, and RG-33
  - System Development & Integration
  - Analyses
  - Installation Manuals
  - VAL/VER Kit
  - Spare Parts
  - Initial Production
  - Level III TDP
- New MRAP Scope
  - MaxxPro Dash CI
  - MATV CP 11-12
  - Caiman Ambulance
- Other Significant Efforts
  - Command & Control On The Move (C2OTM)
    - Caiman
    - Stryker
    - MATV
  - LAV-R Upgrade
  - Robotic Deployment System
  - MRAP Egress Assistance Trainer
  - Universal Combat Lock Tool

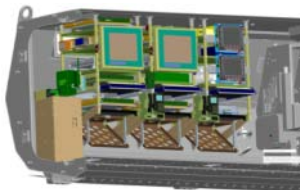


## Sample Deliverables

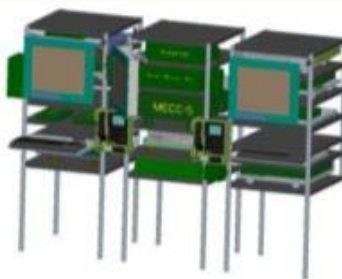
# SYSTEMS ENGINEERING AND INTEGRATION



Updated Architecture Requirement



Updated Architecture Requirement



Systems Integration Lab



Fully Integrated Test Asset



Fully Integrated Caiman First Unit Equipped Asset



8 Vehicle A Kits for Installation



2 Spare Kits



1 Validation Kit

Antenna Analysis  
Power Analysis  
Thermal Analysis  
Blast Analysis  
HFE Analysis  
Safety Analysis

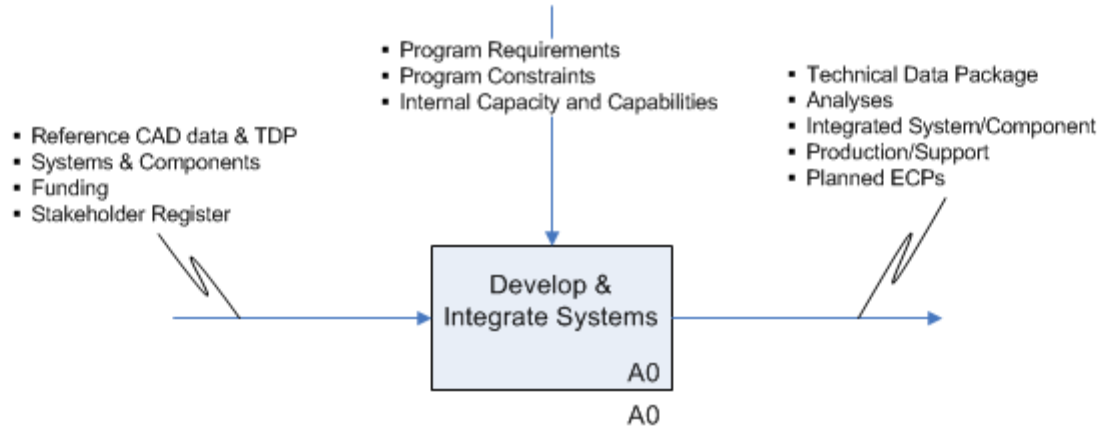
Level II  
Drawings

FSR  
Level  
Install-  
Manuals

Level III  
Drawing  
Package

# System Development & Integration Process

# SYSTEMS ENGINEERING AND INTEGRATION

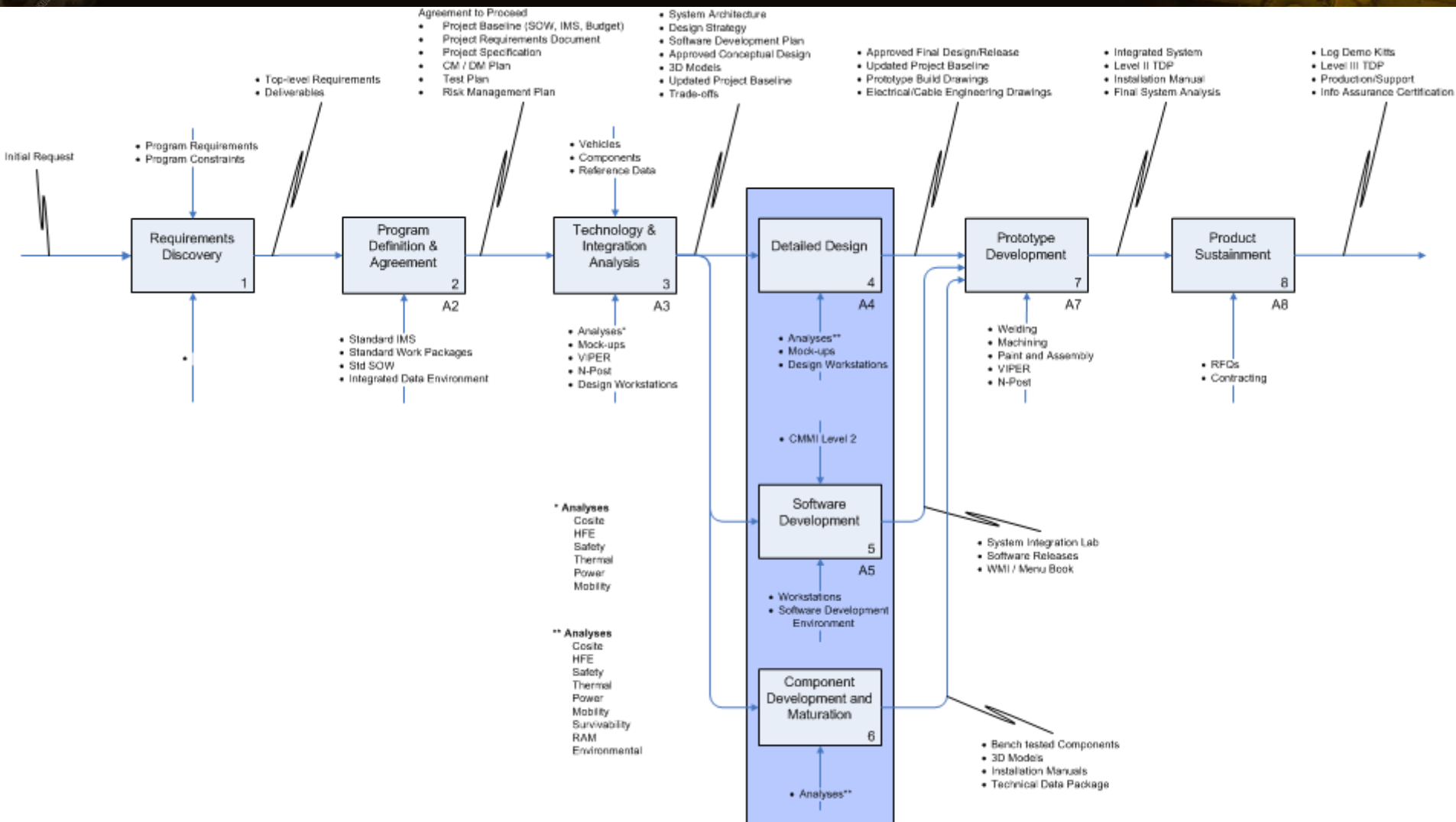


**Purpose:** To ensure rigorous system engineering principles are applied in a repeatable fashion to all TARDEC System Development & Integration projects



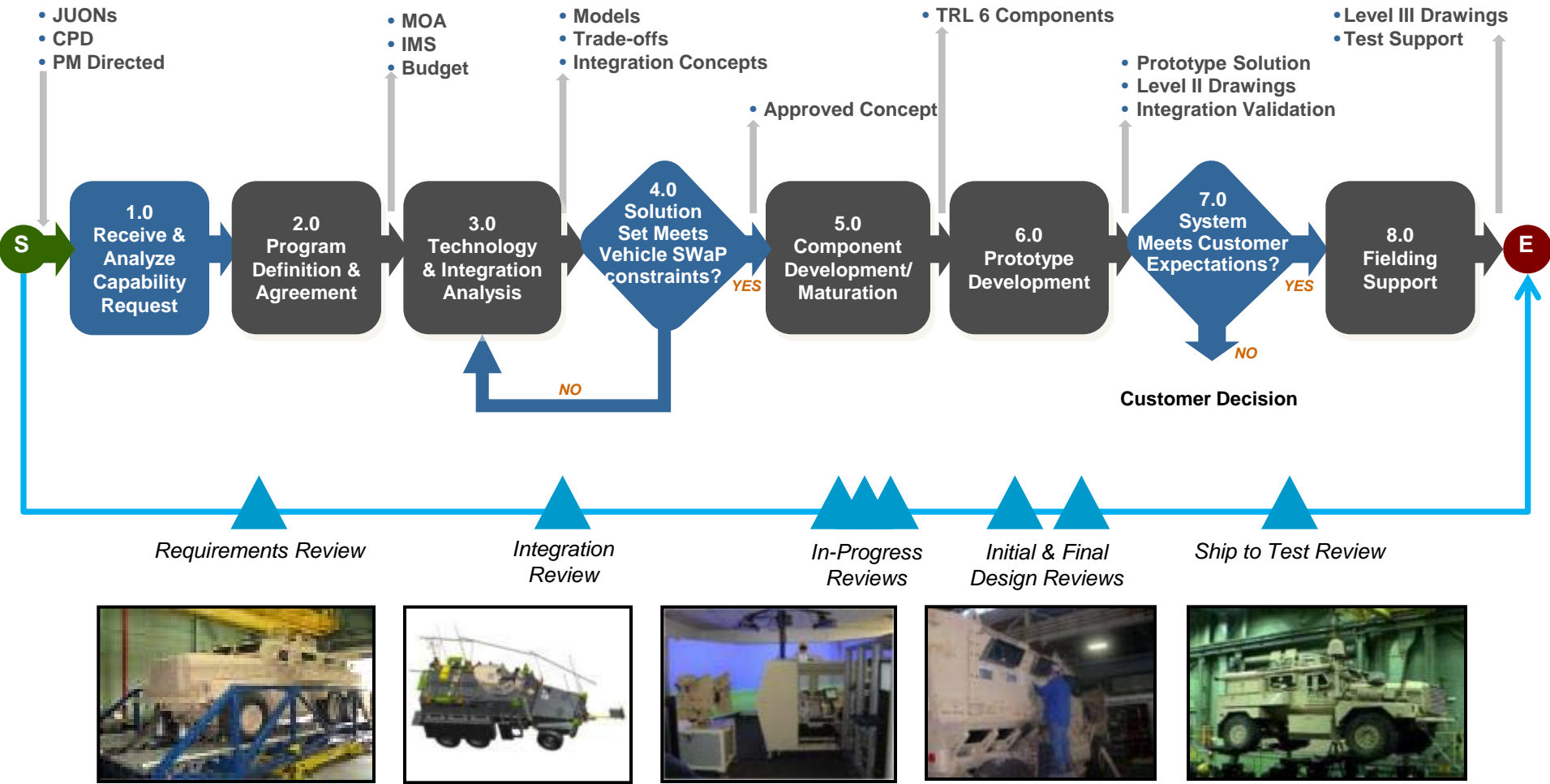
# System Development & Integration Process

# SYSTEMS ENGINEERING AND INTEGRATION

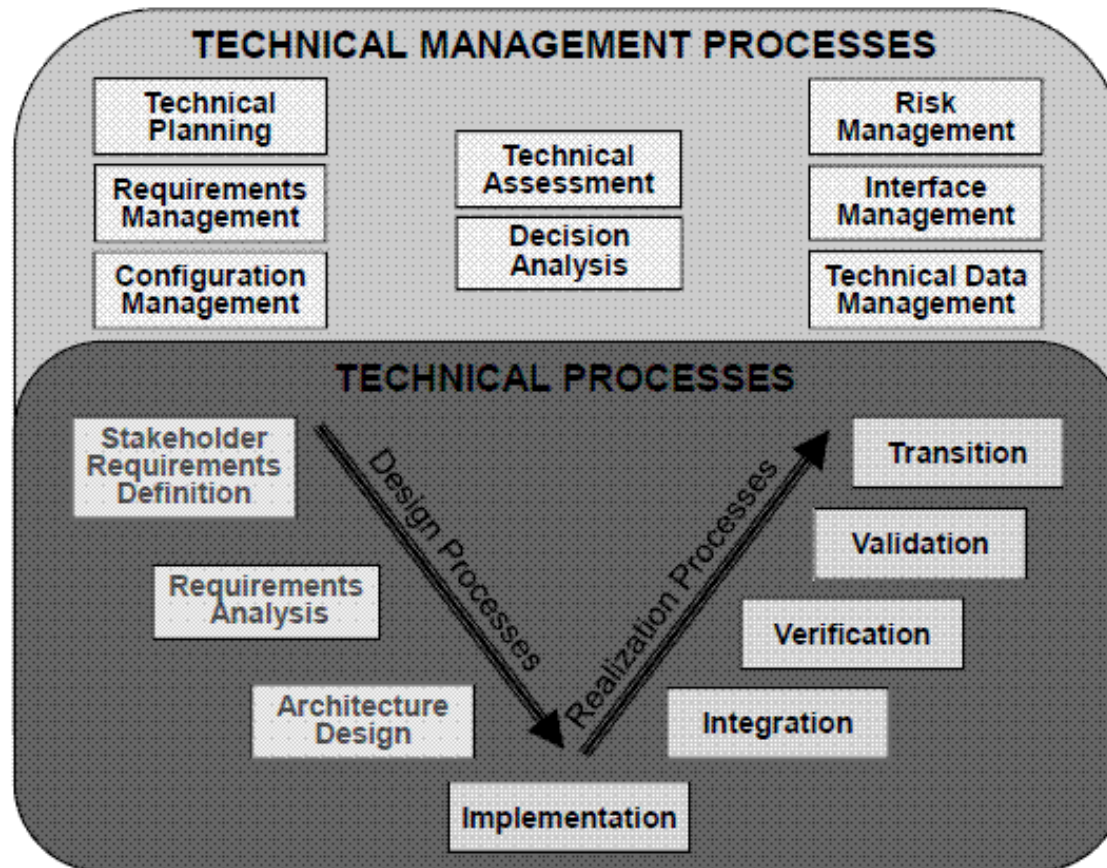


# System Integration Process

# SYSTEMS ENGINEERING AND INTEGRATION

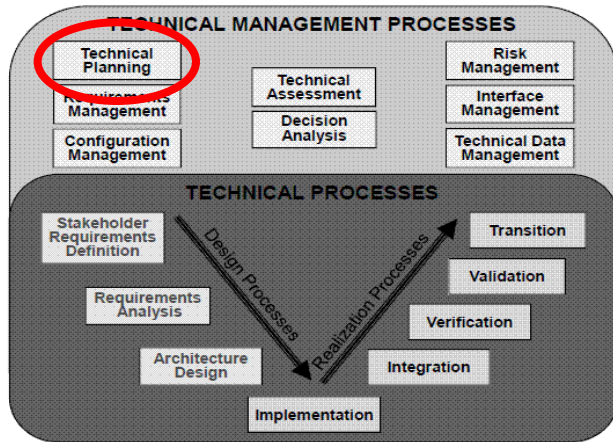


# SYSTEMS ENGINEERING AND INTEGRATION



## DEPARTMENT OF DEFENSE SYSTEMS ENGINEERING PROCESS MODEL 2009

# SYSTEMS ENGINEERING AND INTEGRATION

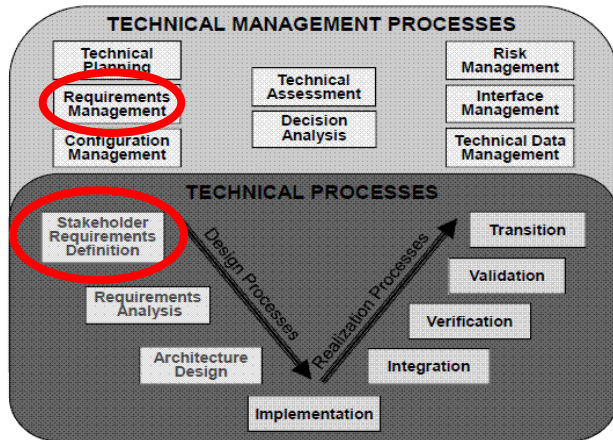


## TECHNICAL PLANNING

- Infused SE Processes Throughout the CGVDI System Development & Integration Process.
- Developed and Documented a Systems Engineering Plan (SEP) to Layout Operating Process.
  - ❑ Form the Basis for Developing Standard Operating Procedures (SOPs).
- Foundation for Planning “What” SE Processes to Implement and “How” to Implement.



# SYSTEMS ENGINEERING AND INTEGRATION



## STAKEHOLDER REQUIREMENTS DEFINITION

### ■ Requirements Management Process Implemented to:

- ✓ Capture Project Requirements
- ✓ Organize Project Requirements
- ✓ Analyze Project Requirements
- ✓ Trace Project Requirements

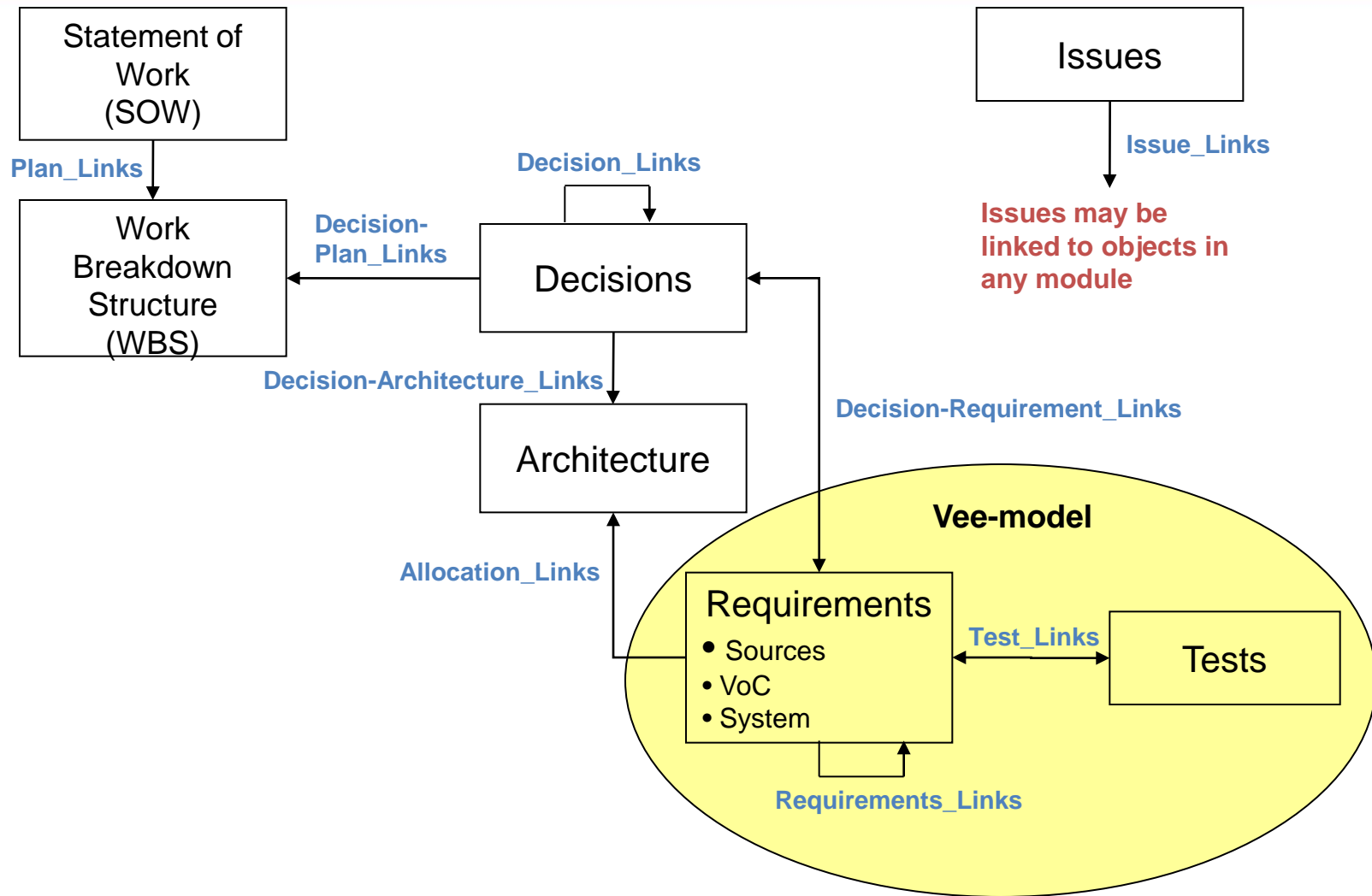
### ■ Requirements Gathering From Sources Such As:

- Project Statement of Work
- Customer Input/Documents
- System Requirements
- Derived Requirements
- Lessons Learned

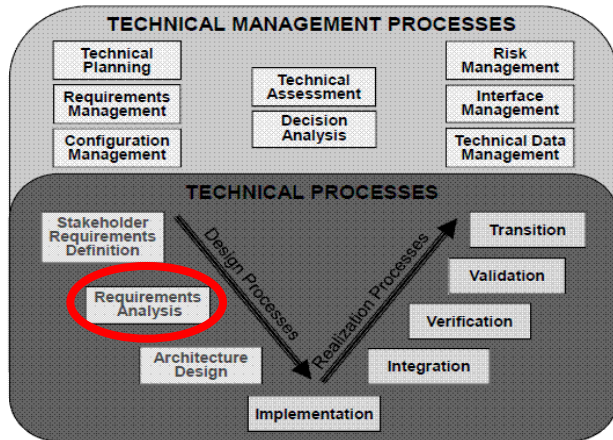


# REQUIREMENTS INFORMATION MODEL

# SYSTEMS ENGINEERING AND INTEGRATION



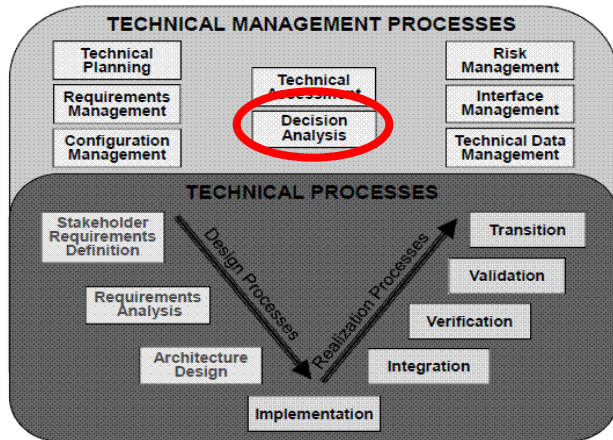
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## REQUIREMENTS ANALYSIS

- Requirements Decomposition – Ensures Requirements are:
  - ✓ Singular
  - ✓ Concise
  - ✓ Unambiguous
  - ✓ Verifiable
- Requirements Traceability– Provides Confidence in Project Completion (Gap Analysis) :
  - ✓ All Requirements Are Allocated to Architecture/Solution
  - ✓ All Requirements Are Linked to Verification Method

# SYSTEMS ENGINEERING AND INTEGRATION



## DECISION ANALYSIS

- Alternative Solutions Selection
  - Define Criteria
  - Assign Weighting Factors
  - Assign Relative Category Importance (Cost, Schedule, Performance)

# DECISION ANALYSIS TOOL

# SYSTEMS ENGINEERING AND INTEGRATION

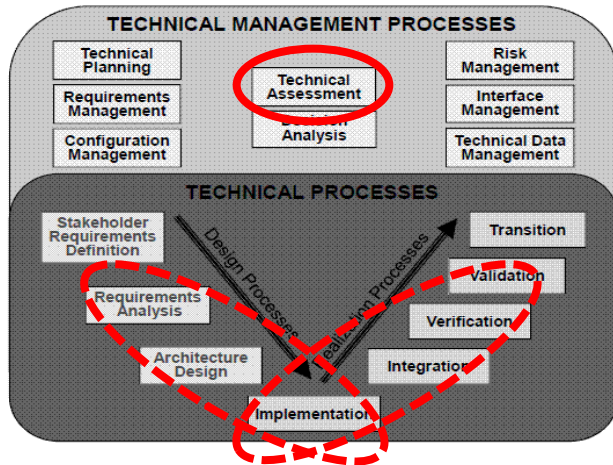
Vehicle Winch Alternative Selection Matrix				Category Weight								
Criteria	Scoring Quantifiers	Weighting Factor (Priority Within Category 1-Low to 10-High)	Normalized Weighting Factor	Option 1 Raw Score	Option 1 Criteria Value	Option 1 Weighted Score	Option 2 Raw Score	Option 2 Criteria Value	Option 2 Weighted Score	Option 3 Raw Score	Option 3 Criteria Value	Option 3 Weighted Score
<b>Performance</b>		30%										
		8	0.0369231	9		0.3323077	3		0.1107692	3		0.110769
Criteria 1	3 = > criteria value 6 = <= criteria value < 9 9 = < criteria value	6	0.0276923	9		0.2492308	9		0.0830769	6		0.166154
		6	0.0276923	6		0.1661538	6		0.1661538	6		0.166154
		6	0.0276923	9		0.2492308	9		0.2492308	9		0.249231
		1	0.0046154	3		0.0138462	3		0.0138462	3		0.013846
		5	0.0230769	3		0.0692308	6		0.1384615	3		0.069231
		5	0.0230769	3		0.0692308	3		0.0692308	3		0.069231
		10	0.0461538	9		0.4153846	6		0.2769231	6		0.276923
		10	0.0461538	9		0.4153846	3		0.1384615	3		0.138462
Criteria n		8	0.0369231	3		0.1107692	3		0.1107692	3		0.110769
Subtotal		65										
Weighted Subtotal						2.0907692			1.3569231			1.370769
<b>Schedule</b>		50%										
Criteria 1		10	0.1470588	6		0.8823529	9		1.3235294	9		1.323529
		4	0.0588235	9		0.5294118	9		0.5294118	9		0.529412
		10	0.1470588	3		0.4411765	3		0.4411765	3		0.441176
		10	0.1470588	3		0.4411765	3		0.4411765	3		0.441176
Criteria n												
Subtotal		34										
Weighted Subtotal						2.2941176			2.7352941			2.735294
<b>Cost</b>		20%										
Criteria 1		10	0.0377358	6		0.2264151	6		0.2264151	6		0.226415
		8	0.0301887	9		0.2716981	6		0.1811321	9		0.271698
		7	0.0264151	9		0.2377358	6		0.1584906	6		0.158491
		1	0.0037736	6		0.0226415	3		0.0113208	3		0.011321
		2	0.0075472	0		0	0		0	0		0
		9	0.0339623	4		0.1358491	1		0.0339623	3		0.101887
Criteria n		8	0.0301887	3		0.090566	3		0.090566	3		0.090566
		8	0.0301887	3		0.090566	3		0.090566	3		0.090566
Subtotal		53										
Weighted Subtotal						1.0754717			0.7924528			0.950943
Grand Total		100%				5.4603556			4.88467			5.057007

Total Option Score – Highest Value Chosen

Total Option Score – Highest Value Chosen



# SYSTEMS ENGINEERING AND INTEGRATION

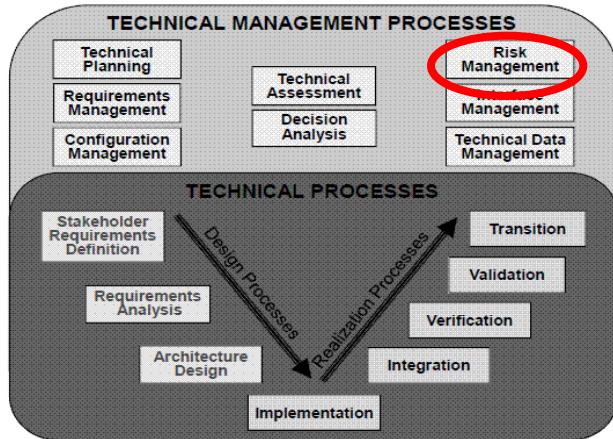


## TECHNICAL ASSESSMENT

- Technical Reviews Based On Formal Reviews Defined in Defense Acquisition Guidebook.
  - Less Formal Implementation (Formal Reviews Reserved for Major Defense Acquisition Programs)
- Reviews Include:
  - ✓ Project Requirements Review
  - ✓ Project Functional Review
  - ✓ Integration Review
  - ✓ Initial Design Review
  - ✓ Final Design Review
  - ✓ Risk Management Reviews
  - ✓ Stakeholder Integrated System Review
  - ✓ Functional Verification Audit
- Entry/Exit Criteria Used To Determine Outcome (Pass, Fail, Pass with Follow-Up).



# SYSTEMS ENGINEERING AND INTEGRATION

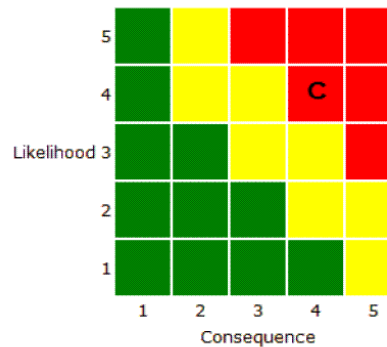


## RISK MANAGEMENT

- Project Risks Continuously Evaluated In Areas Such As:
  - Performance
  - Cost
  - Schedule
- Risks Managed Using Risk Management Tool called “Risk Recon” Developed by Program Executive Office (PEO) Ground Combat Systems (GCS).

# SYSTEMS ENGINEERING AND INTEGRATION

## RISK MANAGEMENT TOOL



Home Reports New Users Help Users: Project: No Project Loaded...

**Classified data must not be stored in this risk management tool**

### Home Page

**General Project Information**

Project: Click 'Open Project' to load a project or click 'New Project' to create a new project

Organization: TBD

PMO: TBD

Product: TBD

Program: TBD

Open Project

**Risks Assigned to this Project**

**Risk Review Board**

**Risk Management Team**

Classified data must not be stored in this risk management tool

Home Page

General Project Information

Project: test three

Organization: HBCT Test Org

PMO: HBCT Test PMO

Product: HBCT Training

Program: HBCT Training

Open Project Edit Project

Risk Review Board

View Risk\_RRB\_HBCTTraining

Risk Management Team

View HBCT Test Mgmt Team

Risks Assigned to this Project

	Status Report	Info Sheet	Detailed Analysis	ID	Risk/Name	Status	Lead	Opened Date	Consequence	Likelihood
Edit View View View				701	To - Test V4.5	In Planning		3/24/2010	(4) Critical	(2) Low Likelihood
Edit View View View				827	Car ran out of gas	Closed		1/8/2010	(2) Marginal	(8) Near Certainty
Edit View View View				558	Class work end on time	Baseline		1/13/2010	(3) Moderate	(8) Moderate
Edit View View View				822	Data Loss	Examined		4/2/2010	(4) Critical	(3) Moderate
Edit View View View				628	Faulty Brakes	Closed		1/8/2010	(2) Marginal	(3) Moderate
Edit View View View				001	Global Warming due to fossil fuels	In Planning		2/17/2010	(4) Critical	(8) Moderate
Edit View View View				825	Hitting a deer	Baseline		1/8/2010	(4) Critical	(4) Highly Likely
Edit View View View				587	Loss of power in a thunderstorm	In Planning		10/27/2009	(4) Critical	(4) Highly Likely
Edit View View View				748	Operating system rollout data moved up	Baseline		3/17/2010	(4) Critical	(8) Moderate
Edit View View View				617	Parking lot accidents	In Planning		1/8/2010	(3) Moderate	(2) Low Likelihood
Edit View View View				557	Risk 01	In Planning		12/14/2009	(3) Moderate	(3) Moderate
Edit View View View				567	Risk 02	In Planning		12/17/2009	(3) Moderate	(3) Moderate
Edit View View View				593	Risk 04	In Planning		12/17/2009	(3) Moderate	(3) Moderate
Edit View View View				002	Risk 05	In Planning		12/24/2009	(4) Critical	(8) Moderate
Edit View View View				787	Risk 08	Examined		3/23/2010	(3) Moderate	(3) Moderate
Edit View View View				652	GIL delay	In Planning		1/21/2010	(4) Critical	(4) Highly Likely
Edit View View View				620	Vehicle Theft	Watch List		1/7/2010	(3) Moderate	(8) Moderate

Create New Risk



# SUMMARY

## SYSTEMS ENGINEERING AND INTEGRATION



- The Systems Engineering Revitalization In the Department Of Defense is Gaining Momentum At TARDEC Through the Systems Engineering Group's Effort.
- The Center For Ground Vehicle Development And Integration's System Development And Integration Process Has Become An Excellent Implementation Of The Systems Engineering Process Model.